AD-A127 949 VELOCITY DISCRIMINATION IN THE PERIPHERAL VISUAL FIELD (U) SMITH-KETTLEWELL INST OF VISUAL SCIENCES SAN FRANCISCO CA MEDICAL RESEARCH INST* S P MCKEE 1/1

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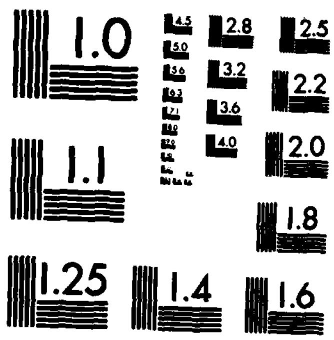

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Human observers can discriminate differences in velocity of about 6% everywhere in the visual field. In the periphery the optimum velocity is faster than the optimum range in the fovea. The basis of velocity discrimination is the angular velocity of the target, not the temporal frequency of the stimulus.

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Research Progress and Forecast Report - McKee

I. Velocity Discrimination in the Peripheral Visual Field

For over a century, there has been speculation that motion parallax could be used by the human visual system to estimate relative distance. As an observer moves past a stationary scene, differences in object distances are translated into differences in retinal velocities. Given the exquisite sense of depth supplied by binocular disparity, the distance information provided by motion parallax might seem superfluous, but disparity detection suffers from some significant limitations. Fine stereoacuity is a property of the central fovea; stereoacuity declines more rapidly with eccentricity than does resolution acuity. Moreover, stereoacuity is degraded by rapid image motion (velocities >2 deg/sec). For the moving observer, the only reliable information about object distances in the peripheral visual field may come from motion parallax. Ultimately the precision of this distance information depends on the human ability to discriminate differences in velocity.

Velocity discrimination for bright line targets was measured in the fovea and in the lower visual field for velocities ranging from 1 to 50 deg/sec. The left half of Figure 1 shows the differential velocity thresholds, as Weber fractions, for the fovea and for two eccentricities (20° and 40°). Surprisingly, the minimum detectable difference in velocity is the same in the periphery as in the fovea — about 6%. In the periphery, this minimum is found at a faster range of velocities.

The peripheral curves are similar to the foveal curve in shape, but are spread laterally along the velocity axis. It seemed possible that some transformation might superimpose the three curves. A natural scaling factor in this context is the psychophysical measure of the cortical magnification function, the minimum angle of resolution with eccentricity. In the right half of Figure 1, velocity has been transformed, using resolution measurements from each subject, into the resolution-units/second appropriate to each retinal locus. To a first approximation, the plotted data points are now coincident. The spatial determinants of velocity discrimination must be changing at a pace dictated by the spatial properties of the retina or primary visual cortex.

Our results suggest that the detection of small differences in velocity does not depend on a fine spatial representation of the moving stimulus; the coarse sampling provided by the peripheral retina will suffice. This degree of precision does require that the temporal sensitivity of the periphery be nearly equal to the temporal sensitivity of the fovea. Several studies from other laboratories indicate that temporal detection (asynchrony, flicker) in the periphery is quite good. Our laboratory is presently exploring the temporal properties of the peripheral visual field in some detail.

What is the functional value of this precise response in the periphery to fast velocities? An observer of average height looking straight ahead and walking at a pace of 2 meters/sec will be exposed to optical velocities of 35^{o}/sec from ground points two paces ahead. Thus he will be able to fixate points on the horizon plane and still have optimal registration of velocity information (and relative distance) at a retinal eccentricity of 40^{o}.

II. Precise Discrimination of Velocity Despite Random Variations in Target Spatial Frequency

To be truly useful in interpreting the surroundings, velocity information should be independent of the figural or spatial characteristics of the stimulus. The judged speed of a moving object should not vary significantly whether the object is a motorcycle or a bus. This study examined the effect of random variations in the spatial frequency of the moving stimulus on the differential velocity threshold.

An unusual procedure is employed in this laboratory to measure the discrimination of velocity. On each trial, the subject is shown one of five velocities chosen from a narrow range, and is forced to indicate whether the presented velocity is faster or slower than the mean of the chosen set. No standard or comparison velocity is supplied; the subject is judging the target velocity against an implicit, internal, standard established by the sequence of trials. This procedure produces increment thresholds as low as any in the experimental literature: a well-trained observer can detect differences in velocity amounting to 4 - 6%. For this type of study, our procedure has a special virtue. As there is no explicit standard, the particular spatial properties of the standard cannot influence the subject's judgment.

The minimum detectable difference in velocity was measured in the fovea for high contrast (83%) sinusoidal gratings moving at a mean velocity of 5 deg/sec. During an experimental session, the spatial frequency of the target was varied randomly from trial to trial and the subject was given no feedback as to the correctness of his answers. Five different spatial frequencies, covering the range from 0.5 cyl/deg to 1.5 cyl/deg, were used. As a control experiment the differential velocity threshold for a single spatial frequency (1 cyl/deg) moving at 5 deg/sec was also measured.

The use of periodic stimuli raises some special questions about the basis of velocity detection. Is the subject actually responding to velocity _per se_ or to the temporal frequency of the target, as has been suggested by previous work on perceived velocity? Random variations in target spatial frequency will, of course, introduce random variations in temporal frequency, variations which are not correlated well with the velocity variations. Thus, judgments based on temporal frequency alone would produce large errors in the velocity judgments and very high differential velocity thresholds. In fact, the velocity thresholds were only slightly affected by the random variation in target spatial frequency. The threshold for a single frequency stimulus (control experiment) was about 5%, and for the mixture of frequencies about 7%. A second experiment in which nine spatial frequencies were randomly interspersed from trial to trial produced exactly the same small change in detectability.

There is second method of examining the effect of target spatial frequency (or temporal frequency) on velocity judgments. If separate psychometric functions are plotted for each spatial frequency included in the random mixture, then the point of subjective equality — the subjective velocity which best matches the true mean velocity — can be measured for each of the tested frequencies. Figure 2 shows the perceived velocity derived from the median shifts in the psychometric functions. Clearly the overwhelming influence in velocity detection is target velocity, not temporal frequency. Nevertheless, these data show that spatial frequency does influence the judgments slightly. High frequency stimuli appear to moving somewhat faster on the average than low frequency stimuli.

Our next experiments will examine the spatial filter characteristics of the mechanisms responsible for the precise discrimination of velocity. We will use one-dimensional "DOG" patterns (luminance distributions based on the Difference of Gaussians) to determine the ideal stimulus. A special image generator, which can be addressed by our microcomputer, has been designed and built in-house for these experiments.

III. Publications

McKee, S.P. and Nakayama, K. The detection of motion in the peripheral visual field. (Accepted for publication in Vision Research)

McKee, S.P. and Nakayama, K. Precise velocity discrimination despite random variations in target spatial frequency. (In preparation)

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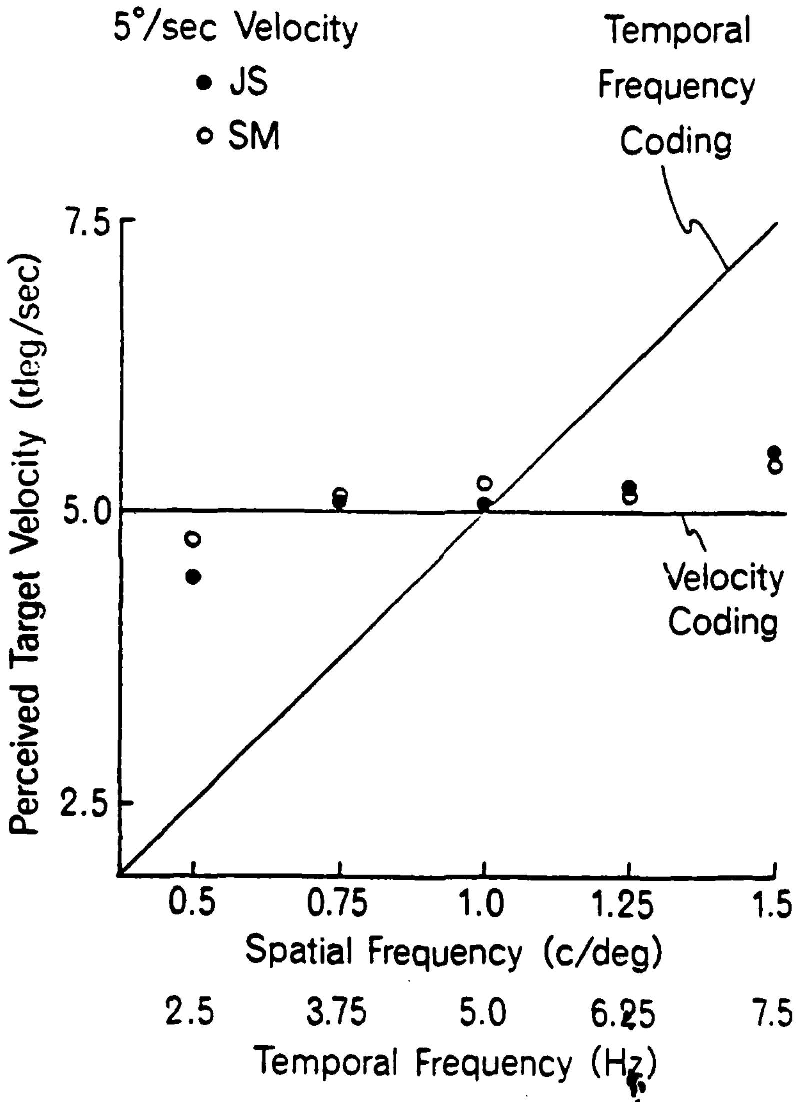
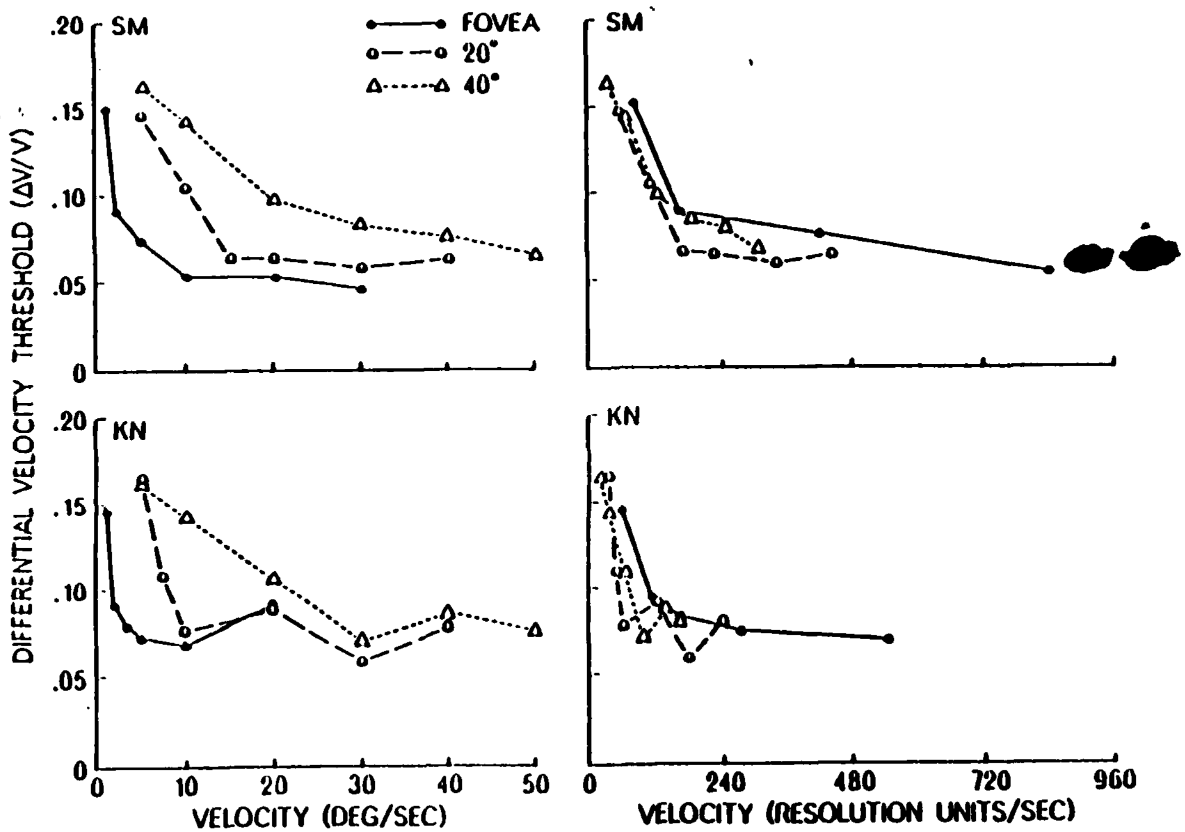

5°/sec Velocity
JS
SM
Temporal Frequency Coding
Velocity Coding
Perceived Target Velocity (deg/sec)
7.5
5.0
2.5
0.5
0.75
1.0
1.25
1.5
Spatial Frequency (c/deg)
2.5
3.75
5.0
6.25
7.5
Temporal Frequency (Hz)



McKee & Nakayama Figure 6

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